Name: Cicelia Siu

CS 219 – Assignment #8

Purpose: Become familiar with basic cache implementation and operation

Points: 60

Reading/References: Chapter 5

Assignment:

Answer the following questions:

1-4) A series of address references generated in order (0-7) by the microprocessor are provided. The table shows the address references (in binary) and the data stored at that address (in decimal).

The cache uses 4 bytes per block. All data items shown are word sized values. Assume a 2-way set associative cache design that uses the LRU algorithm (with a cache that can hold atotal of 4 blocks). Assume that the cache is initially empty.

1. Determine the *tag*, *line/set*, and *offset* fields and fill in the appropriate table (first table).

(2 pts)

1. In the provided table (second table), insert for each access the tag (in binary), valid bit (0/1), least recently used (0/1), and data (in decimal) for each access. Use the provided tables (next page). Assume any unprovided data items are all set to 0. (10 pts)

What is the hit ratio for this access sequence (hits/accesses) as a percentage? (3 pts)

**Question #1**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| address | 10001100 | 10110010 | 10111110 | 10001100 | 10011100 | 11101000 | 11111110 | 11101000 |
| data | 3 | 32 | 98 | **3** | 51 | 48 | 42 | 48 |
| tag | 10001 | 10110 | 10111 | 10001 | 10011 | 11101 | 11111 | 11101 |
| line/set | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 |
| offset | 00 | 10 | 10 | 00 | 00 | 00 | 10 | 00 |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| access 0 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***0*** | ***-*** | ***-*** | ***-*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| line/set 1 | ***1*** | ***1*** | ***10001*** | ***3*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| access 1 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***10110*** | ***32*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| line/set 1 | ***1*** | ***1*** | ***10001*** | ***3*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| access 2 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***10110*** | ***32*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| line/set 1 | ***1*** | ***0*** | ***10001*** | ***3*** |  | ***1*** | ***1*** | ***10111*** | ***98*** |
| access 3 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***10110*** | ***32*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| line/set 1 | ***1*** | ***1*** | ***10001*** | ***3*** |  | ***1*** | ***0*** | ***10111*** | ***98*** |
| access 4 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***10110*** | ***32*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| line/set 1 | ***1*** | ***0*** | ***10001*** | ***3*** |  | ***1*** | ***1*** | ***10011*** | ***51*** |
| access 5 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***0*** | ***10110*** | ***32*** |  | ***1*** | ***1*** | ***11101*** | ***48*** |
| line/set 1 | ***1*** | ***0*** | ***10001*** | ***3*** |  | ***1*** | ***1*** | ***10011*** | ***51*** |
| access 6 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***0*** | ***10110*** | ***32*** |  | ***1*** | ***1*** | ***11101*** | ***48*** |
| line/set 1 | ***1*** | ***1*** | ***11111*** | ***42*** |  | ***1*** | ***0*** | ***10011*** | ***51*** |
| access 7 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***0*** | ***10110*** | ***32*** |  | ***1*** | ***1*** | ***11101*** | ***48*** |
| line/set 1 | ***1*** | ***1*** | ***11111*** | ***42*** |  | ***1*** | ***0*** | ***10011*** | ***51*** |

Hit Ratio: 3, 48

**2/8 = 25%**

**Question #2**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| address | 11000000 | 11111110 | 11000100 | 11001000 | 10011100 | 11001100 | 11010000 | 11010100 |
| data | 25 | 24 | 35 | 45 | 28 | 55 | 65 | 75 |
| tag | ***11000*** | ***11111*** | ***11000*** | ***11001*** | ***10011*** | ***11001*** | ***11010*** | ***11010*** |
| line/set | ***0*** | ***1*** | ***1*** | ***0*** | ***1*** | ***1*** | ***0*** | ***1*** |
| offset | ***00*** | ***10*** | ***00*** | ***00*** | ***00*** | ***00*** | ***00*** | ***00*** |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| access 0 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***11000*** | ***25*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| line/set 1 | ***0*** | ***-*** | ***-*** | ***-*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| access 1 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***11000*** | ***25*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| line/set 1 | ***1*** | ***1*** | ***11111*** | ***24*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| access 2 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***11000*** | ***25*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| line/set 1 | ***1*** | ***0*** | ***11111*** | ***24*** |  | ***1*** | ***1*** | ***11000*** | ***35*** |
| access 3 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***0*** | ***11000*** | ***25*** |  | ***1*** | ***1*** | ***11001*** | ***45*** |
| line/set 1 | ***1*** | ***0*** | ***11111*** | ***24*** |  | ***1*** | ***1*** | ***11000*** | ***35*** |
| access 4 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***0*** | ***11000*** | ***25*** |  | ***1*** | ***1*** | ***11001*** | ***45*** |
| line/set 1 | ***1*** | ***1*** | ***10011*** | ***28*** |  | ***1*** | ***0*** | ***11000*** | ***35*** |
| access 5 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***0*** | ***11000*** | ***25*** |  | ***1*** | ***1*** | ***11001*** | ***45*** |
| line/set 1 | ***1*** | ***0*** | ***10011*** | ***28*** |  | ***1*** | ***1*** | ***11001*** | ***55*** |
| access 6 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***11010*** | ***65*** |  | ***1*** | ***0*** | ***11001*** | ***45*** |
| line/set 1 | ***1*** | ***0*** | ***10011*** | ***28*** |  | ***1*** | ***1*** | ***11001*** | ***55*** |
| access 7 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***11010*** | ***65*** |  | ***1*** | ***0*** | ***11001*** | ***45*** |
| line/set 1 | ***1*** | ***1*** | ***11010*** | ***75*** |  | ***1*** | ***0*** | ***11001*** | ***55*** |

Hit Ratio: **0/8 = 0%**

**Question #3**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| address | 10001100 | 11101010 | 10001100 | 11101110 | 11101010 | 10001100 | 11101010 | 11101110 |
| data | 51 | 21 | 51 | 91 | 21 | 51 | 21 | 91 |
| tag | ***10001*** | ***11101*** | ***10001*** | ***11101*** | ***11101*** | ***10001*** | ***11101*** | ***11011*** |
| line/set | ***1*** | ***0*** | ***1*** | ***1*** | ***0*** | ***1*** | ***0*** | ***1*** |
| offset | ***00*** | ***10*** | ***00*** | ***10*** | ***10*** | ***00*** | ***10*** | ***10*** |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| access 0 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***0*** | ***-*** | ***-*** | ***-*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| line/set 1 | ***1*** | ***1*** | ***10001*** | ***51*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| access 1 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***11101*** | ***21*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| line/set 1 | ***1*** | ***1*** | ***10001*** | ***51*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| access 2 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***11101*** | ***21*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| line/set 1 | ***1*** | ***1*** | ***10001*** | ***51*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| access 3 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***11101*** | ***21*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| line/set 1 | ***1*** | ***0*** | ***10001*** | ***51*** |  | ***1*** | ***1*** | ***11101*** | ***91*** |
| access 4 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***11101*** | ***21*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| line/set 1 | ***1*** | ***0*** | ***10001*** | ***51*** |  | ***1*** | ***1*** | ***11101*** | ***91*** |
| access 5 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***11101*** | ***21*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| line/set 1 | ***1*** | ***1*** | ***10001*** | ***51*** |  | ***1*** | ***0*** | ***11101*** | ***91*** |
| access 6 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***11101*** | ***21*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| line/set 1 | ***1*** | ***1*** | ***10001*** | ***51*** |  | ***1*** | ***0*** | ***11101*** | ***91*** |
| access 7 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***11101*** | ***21*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| line/set 1 | ***1*** | ***0*** | ***10001*** | ***51*** |  | ***1*** | ***1*** | ***11101*** | ***91*** |

Hit Ratio: 51,21,51,21,91 , **⅝ = 62.5%**

**Question #4**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| address | 10101000 | 10111110 | 11101000 | 10011100 | 10001100 | 10111100 | 10110010 | 10001100 |
| data | 71 | 21 | 91 | 92 | 31 | 10 | 43 | 31 |
| tag | ***10101*** | ***10111*** | ***11101*** | ***10011*** | ***10001*** | ***10111*** | ***10110*** | ***10001*** |
| line/set | ***0*** | ***1*** | ***0*** | ***1*** | ***1*** | ***1*** | ***0*** | ***1*** |
| offset | ***00*** | ***10*** | ***00*** | ***00*** | ***00*** | ***00*** | ***10*** | ***00*** |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| access 0 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***10101*** | ***71*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| line/set 1 | ***0*** | ***-*** | ***-*** | ***-*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| access 1 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***10101*** | ***71*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| line/set 1 | ***1*** | ***1*** | ***10111*** | ***21*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| access 2 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***0*** | ***10101*** | ***71*** |  | ***1*** | ***1*** | ***11101*** | ***91*** |
| line/set 1 | ***1*** | ***1*** | ***10111*** | ***21*** |  | ***0*** | ***-*** | ***-*** | ***-*** |
| access 3 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***0*** | ***10101*** | ***71*** |  | ***1*** | ***1*** | ***11101*** | ***91*** |
| line/set 1 | ***1*** | ***0*** | ***10111*** | ***21*** |  | ***1*** | ***1*** | ***10011*** | ***92*** |
| access 4 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***0*** | ***10101*** | ***71*** |  | ***1*** | ***1*** | ***11101*** | ***91*** |
| line/set 1 | ***1*** | ***1*** | ***10001*** | ***31*** |  | ***1*** | ***0*** | ***10011*** | ***92*** |
| access 5 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***0*** | ***10101*** | ***71*** |  | ***1*** | ***1*** | ***11101*** | ***91*** |
| line/set 1 | ***1*** | ***0*** | ***10001*** | ***31*** |  | ***1*** | ***1*** | ***10111*** | ***10*** |
| access 6 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***10110*** | ***43*** |  | ***1*** | ***0*** | ***11101*** | ***91*** |
| line/set 1 | ***1*** | ***0*** | ***10001*** | ***31*** |  | ***1*** | ***1*** | ***10111*** | ***10*** |
| access 7 | Block 0 | | | |  | Block 1 | | | |
|  | v | lru | tag | data |  | v | lru | tag | data |
| line/set 0 | ***1*** | ***1*** | ***10110*** | ***43*** |  | ***1*** | ***0*** | ***11101*** | ***91*** |
| line/set 1 | ***1*** | ***1*** | ***10001*** | ***31*** |  | ***1*** | ***0*** | ***10111*** | ***10*** |

Hit Ratio: 31 = **⅛ = 12.5%**